Section C. Magnetic Compass

Overview

Introduction

The magnetic compass, even though it has been around for a long time, is still very important for safely navigating a boat. Whether steering a course out of sight of landmarks or in poor visibility, the magnetic compass is the primary tool for guiding the boat to its destination. (Though used by larger vessels, the gyrocompass will not be discussed since it is not commonly used by boats.)

In this section

These items are discussed in this section:

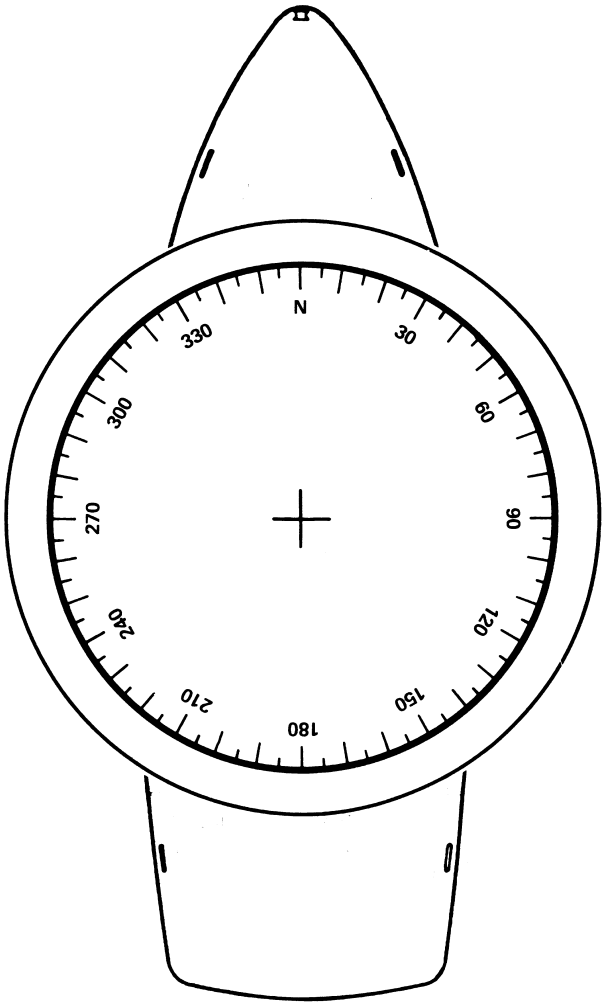
Components of the Magnetic Compass

C.1. General

The magnetic compass is standard equipment on all boats. Mechanically, it is a simple piece of equipment. The magnetic compass is used to determine the boat's heading. A prudent seaman will check its accuracy frequently realizing that the magnetic compass is influenced, not only by the earth's magnetic field, but also by fields radiating from magnetic materials aboard the boat. It is also subject to error caused by violent movement as might be encountered in heavy weather.

C.2. Compass card

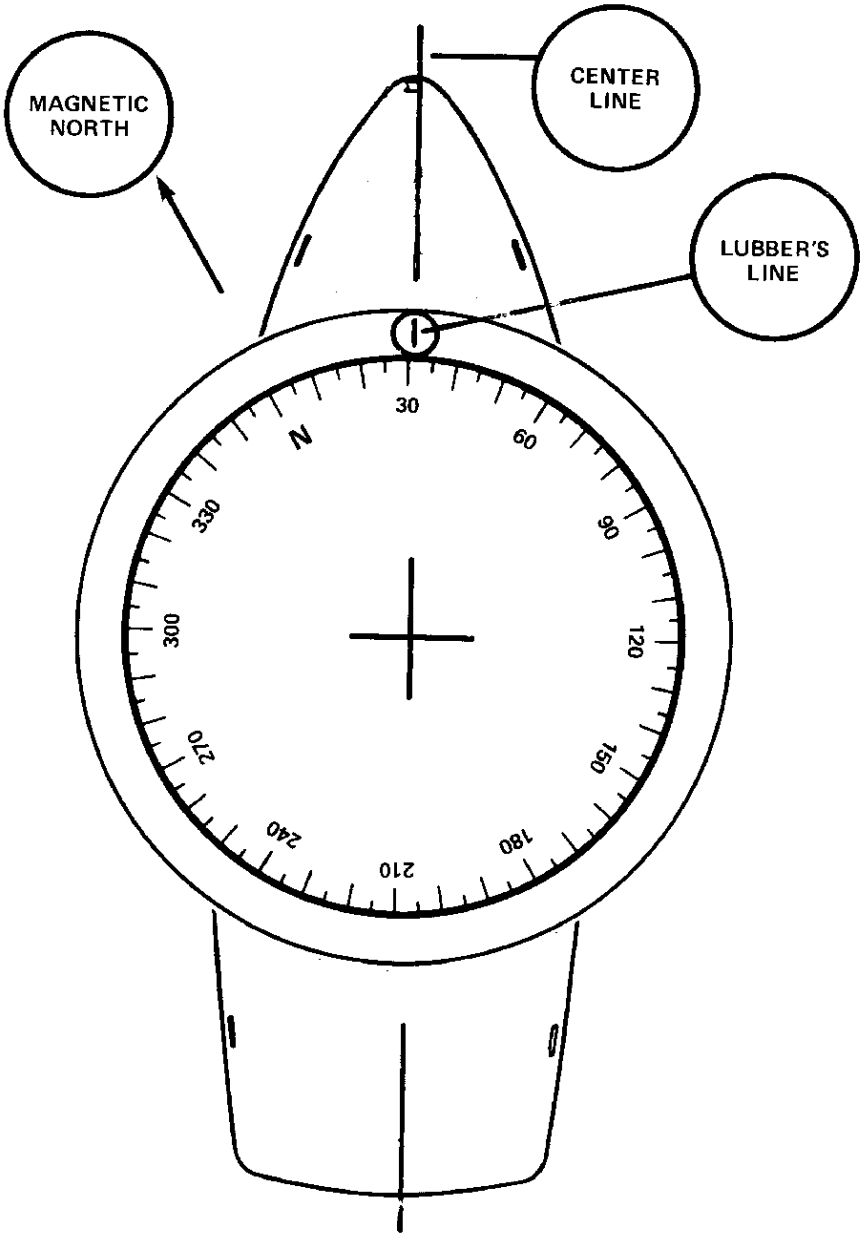
The arc of the compass card is divided into 360 degrees (º) and is numbered all the way around the card from 000º through 360º in a clockwise direction. Attached to the compass card is a magnet that aligns itself with the magnetic field around it. The 'ZERO' (North) on the compass card is in line with the magnet or needle attached to the card. When the boat turns, the needle continues to align itself with the magnetic field. This means the compass card stays stationary and the boat turns around it. (See Figure 14-14)



Compass Card
Figure 14-14

C.3. Lubber's Line

The lubber's Line is a line or mark scribed on the compass housing to indicate the direction in which the boat is heading. The compass is mounted in the boat with the lubber's line on the boat's center line and parallel to its keel. (See Figure 14-15)



Lubber's Line and Magnetic North
Figure 14-15

Direction

C.4. General

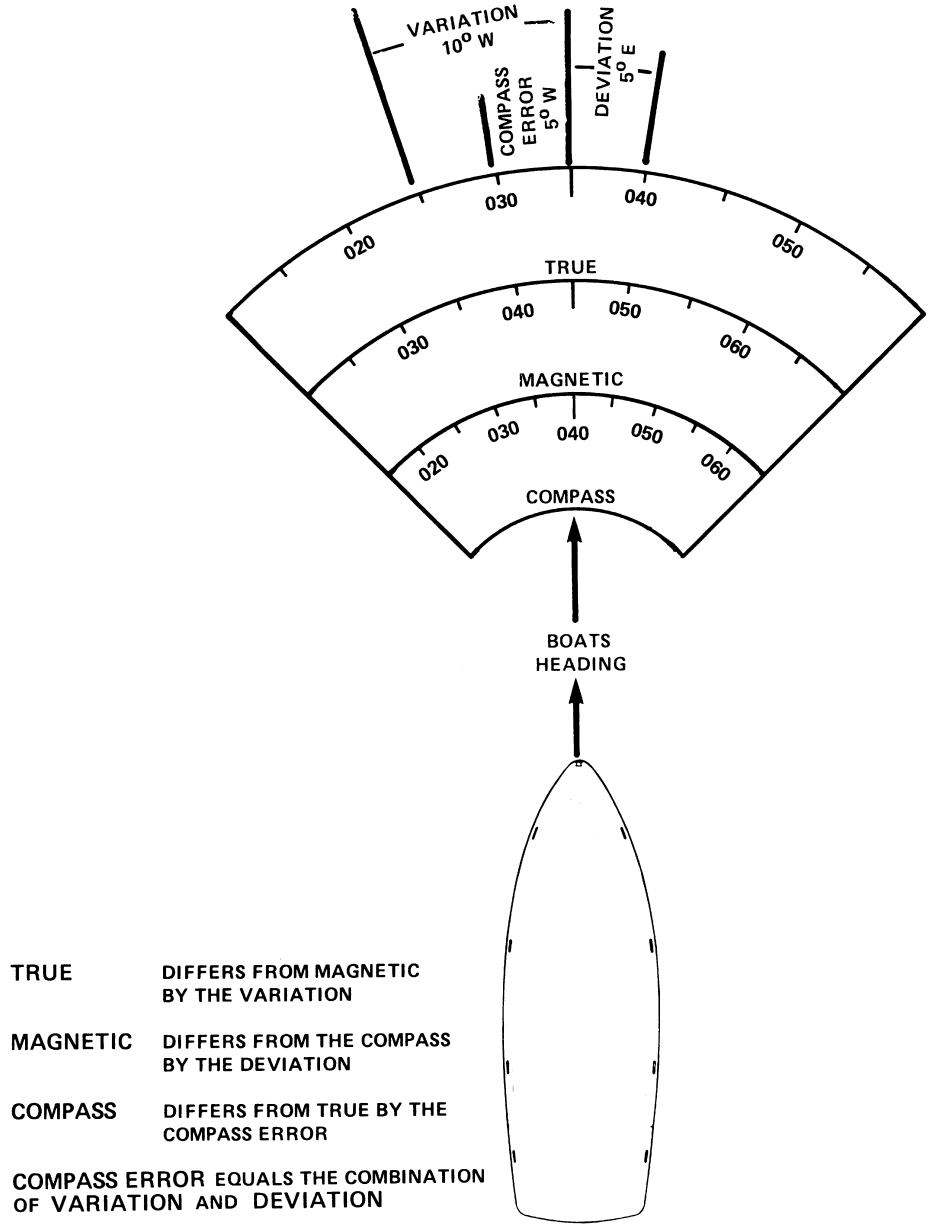
Direction is measured clockwise from 000º to 360º. When speaking of degrees in giving course or heading, always use three digits, such as 270º or 057º.

C.5. True and magnetic

Directions measured on a chart are in true degrees or magnetic degrees.

- True direction uses the North Pole as a reference point.
- Magnetic direction uses the Magnetic North as a reference point.
- True direction differs from magnetic direction by variation.

Directions steered on the compass by the boat are true degrees or magnetic degrees. However, the difference between the true and magnetic heading is compass error. Compass error includes the error of the boat's magnetic compass. This is discussed later. (See Figure 14-16)



True, Magnetic, and Compass Courses
Figure 14-16

Compass Error

C.6. General

Compass error is the angular difference between a compass direction and its corresponding true direction. The magnetic compass reading must be corrected for variation and deviation.

Variation

C.7. General

Variation is the angular difference in degrees between north and magnetic north. It varies according to the location.

C.8. Amount of variation

The amount of variation changes from one point to the next on the earth's surface. It is written in degrees in either an easterly or a westerly direction. The variation is on the inside of the compass rose of the chart.

C.9. Variation increases/ decreases

Increases in variation may continue for many years, sometimes reaching large values, remaining nearly the same for a few years and then reverse its trends (decrease). Predictions of the change of variation are intended for short term use, that is a period of only a few years. The latest charts available should always be used. The compass rose will show the amount of predicted change.

C.10. Calculating the variation

Follow the procedures below for determining the amount of annual increase or decrease of variation:

NOTE

Since variation is caused by the earth's magnetic field, its value changes with the geographic location of the boat. Variation remains the same for all headings of the

Step	Procedure
1	Locate the compass rose nearest to area of operation on the chart.
2	Locate the variation and annual increase/decrease from the center of the compass rose.
3	Locate the year from the center of the compass rose where variation and the year are indicated.
4	Subtract year indicated in the compass rose from the present year.
5	Multiply the number of years difference by the annual increase or decrease.
6	Add or subtract the amount from Step No. 5 to the variation within the compass rose.

Deviation

C.11. General

Deviation is the amount the magnetic compass needle is deflected by magnetic influences of the boat. It can be caused by:

- metal objects around the compass,
- electrical motors,
- and the boat itself.

Deviation creates an error in the compass course that a boat attempts to steer. For navigational accuracy and the safety of the boat and crew, the boat's compass heading must be corrected for deviation so that the actual magnetic course can be accurately steered.

NOTE

Deviation changes with the boat's heading, it is not affected by the geographic location of the boat.

C.12. Deviation table

Coast Guard regulations require unit commanders to ensure compass errors are accurately known and properly recorded and posted. This is accomplished for a magnetic compass by "swinging ship" to determine deviation. A deviation table may be created or the Coast Guard Deviation Table used by ships may be altered for use by boats. (Boats do not fill in the "Degaussing On" column since they do not carry this equipment.) Unit commanders are also required to develop procedures to compensate or calibrate compasses as necessary.

A new deviation table must be completed and approved by the unit commander annually, after yard availabilities, and after addition or deletion of equipment or structural alternations that would affect the magnetic characteristics of the boat. The original deviation table shall be placed in the permanent boat record and a copy posted on the boat near the compass.

C.13. Preparing a deviation table

Since deviation varies from boat to boat, you need to know the effect of deviation on your compass. The amount of deviation is normally determined by "swinging ship" (procedures are discussed later) and recording them on a deviation table. The table is tabulated for every 15º of the compass. Deviation varies for different courses you steer and can be either easterly (E), westerly (W), or no error. Deviation would then be applied to the boat's compass heading to determine the correct magnetic course.

C.14 Deviation by Running a range

A commonly used practice to determine deviation is running a range. A range is a line of bearing made by two fixed objects. Sometimes, specific range marks are installed so that when they are lined up, you are on the center of a channel (and a true or magnetic direction that can be read on the compass rose). Or, check the chart for prominent landmarks that may line up as a natural range.

C.14.a. Finding bearing of a range

When obtaining your deviation, select a position that will not interfere with normal shipping traffic. To find the magnetic bearing of the range:

1. Align the edge of the parallel rulers (or course plotter) so that it passes through the charted positions of the two objects.
2. Line up the edge of the parallel rulers with the center of the nearest compass rose.
3. Read the magnetic bearing off of the inner ring of the compass rose.

NOTE

Man-made ranges may have their direction marked on the chart, if marked, the direction will be in degrees true, not magnetic.

Be sure to read the correct side of the compass rose - going in the wrong direction will give the reciprocal bearing which is 180º in the wrong direction. To go in the correct direction, imagine the boat positioned in the center of the compass rose and looking out towards the range.

C.14.b. Example

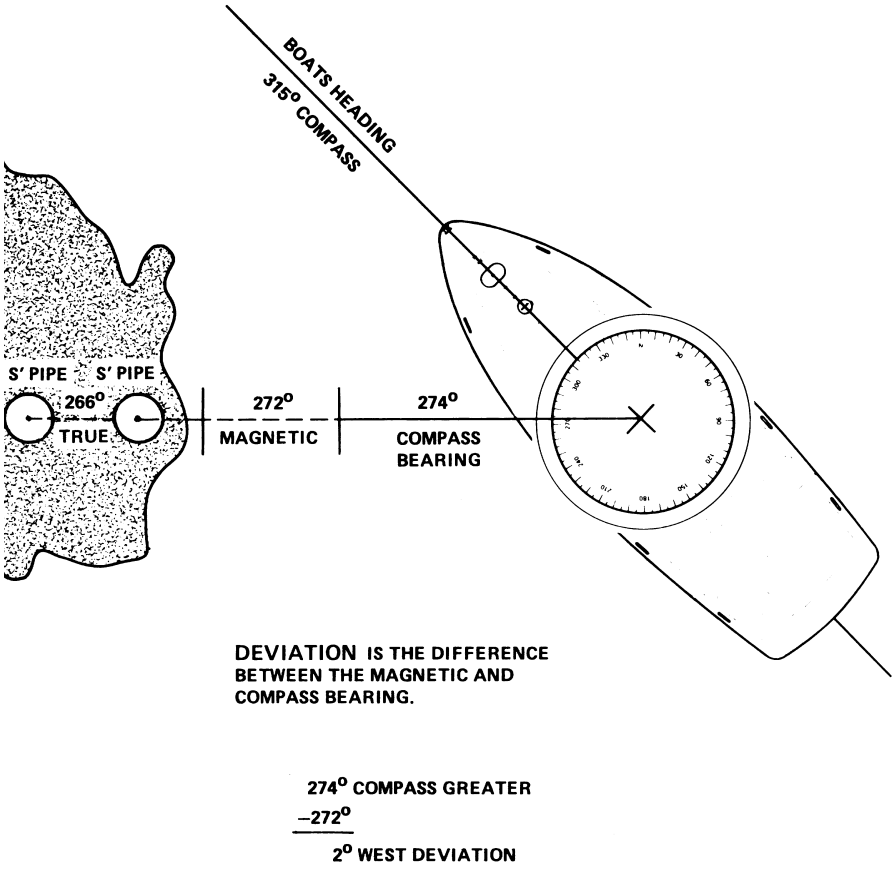
Example: The magnetic bearing (M) of the range measured on the chart is 272º. The bearing of the range read off of the magnetic compass (C) is 274º. (See Figure 14-17)

NOTE

To correct the compass - subtract Easterly errors; add Westerly errors.

Answer: 2ºW is the deviation

The amount of deviation is the difference between C and M, this is 2º. The direction of deviation is based upon “Compass Best, Error West”. Since C is greater than M, the error is west. (This will be discussed in more detail later.)



Obtaining Deviation Using Ranges
Figure 14-17

C.14.c. Exercise

Use the example above and Figure 14-17 for guidance in developing a deviation table. Prepare a work table using the procedures as follows:

NOTE

Enter all compass bearings to the nearest whole degree.

Step	Procedure
1	Enter the boat's compass headings for every 15º in the first column.
2	Enter in the third column the range's magnetic bearing as measured on the chart (272º). It is the same value for all entries.
3	Get the boat underway, at slow speed and in calm water. Steer the boat's compass heading listed in the first column, normally starting with a compass heading of 000º. Steer a steady heading and cross the range.

Step	Procedure
4	Observe the compass bearing of the range at the instant you cross the range. Use 266º for this exercise. Enter the range's bearing by compass in the second column on the same line as the 'Boat's Compass Heading' of 000º.
5	Come around to the boat's compass heading of 015º. Steer a steady heading and cross the range.
6	Observe the compass bearing of the range at the instant you cross the range. Use 265º for this exercise. Enter the range's bearing by compass in the second column on the same line as the 'Boat's Compass Heading' of 015º.
7	Come around to the boat's compass heading of 030º. Steer a steady heading and cross the range.
8	Observe the compass bearing of the range at the instant you cross the range. Use 265º for this exercise. Enter the range's bearing by compass in the second column on the same line as the 'Boat's Compass Heading' of 030º.
9	Continue changing course by 15º increments until you have crossed the range and noted the compass bearing of the range for each for each boat's compass heading. The table is already filled in for this exercise.
10	Having completed "swinging ship", determine deviation for each heading by taking the difference between the magnetic bearing and the compass bearing. (See Figure 14-18)

Boat's Compass Heading	Compass Bearing of Range	Magnetic Bearing of Range	Deviation	Magnetic Course
000º	266º	272º	6°E	006°
015º	265º	272º	7°E	022°
030º	265º	272º	7°E	037°
045º	267º	272º	5°E	050°
060º	270º	272º	2°E	062°
075º	269º	272º	3°E	078°
090º	271º	272º	1°E	091°
105º	272º	272º	0°	105°
120º	267º	272º	5°E	125°
135º	273º	272º	1°W	134°
150º	268º	272º	4°E	154°
165º	275º	272º	3°W	162°
180º	274º	272º	2°W	178°
195º	277º	272º	5°W	190°
210º	278º	272º	6°W	204°
225º	279º	272º	7°W	218°
240º	275º	272º	3°W	237°
255º	279º	272º	7°W	244°
270º	279º	272º	7°W	263°
285º	277º	272º	5°W	280°
300º	270º	272º	2°E	302°
315º	274º	272º	2°W	313°
330º	269º	272º	3°E	333°
345º	266º	272º	6°E	351°

Completed Work Table, Deviation
Figure 14-18

NOTE

When the compass bearing is LESS than the magnetic bearing - deviation (error) is East. When the compass bearing is GREATER than the magnetic bearing - deviation (error) is West.

Step	Procedure
11	Prepare a smooth deviation table to be placed next to the boat's compass. The table must give the deviation for a magnetic course so you can use the table to correct courses. (See Figure 14-19) As noted before, the deviation table used by ships can be altered for use by boats.

Memory Aid

Determining the direction of deviation compass least, error East; compass best, error West

Compass Course	Deviation	Magnetic Course
000º	6°E	006°
015º	7°E	022°
030º	7°E	037°
045º	5°E	050°
060º	2°E	062°
075º	3°E	078°
090º	1°E	091°
105º	0°	105°
120º	5°E	125°
135º	1°W	134°
150º	4°E	154°
165º	3°W	162°
180º	2°W	178°
195º	5°W	190°
210º	6°W	204°
225º	7°W	218°
240º	3°W	237°
255º	7°W	244°
270º	7°W	263°
285º	5°W	280°
300º	2°E	302°
315º	2°W	313°
330º	3°E	333°
345º	6°E	351°

Deviation Table (Mounted Close to Compass)
Figure 14-19

C15. Deviation by multiple observations from one position

An accurately charted object, such as solitary piling, with maneuvering room, and depth, around it must be available. In addition, there must be charted and visible objects, suitable for steering on with accuracy, at a distance of greater than ½ mile. Use the largest scale chart possible.

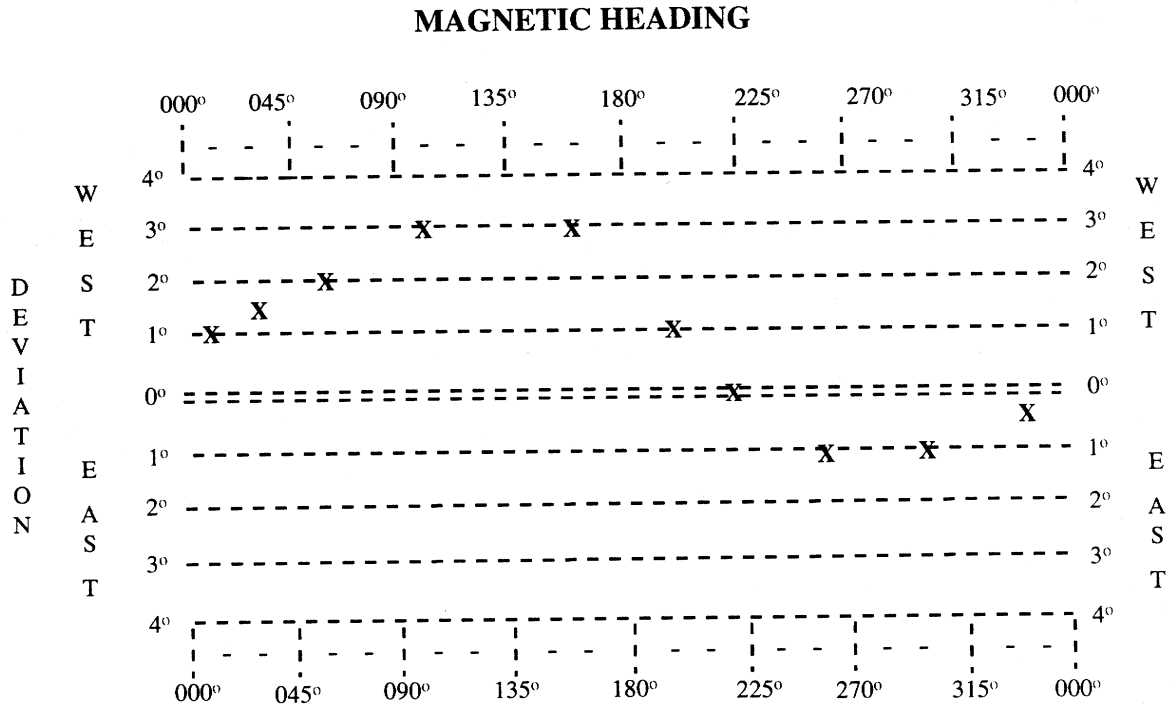
C.15.a. Preparing

Determine and record the magnetic bearing from the chart (from piling to object) of various selected objects. Ideally, the objects should be 15 ° apart. However, this is not necessary as long as a minimum of ten objects/bearings, evenly separated through the entire 360°, are available. For ready reference, record this information as shown in columns (1) and (2) in the table below.

(1) Object (on chart)	(2) Magnetic Heading (plotted)	(3) Compass Heading (measured)	(4) Deviation (calculated)
Steeple	013°	014.0°	1.0°W
Stack	040°	041.5°	1.5°W
R. Tower	060°	062.0°	2.0°W
Lt. #5	112°	115.0°	3.0°W
Left Tangent Pier	160°	163.0°	3.0°W
Water Tower	200°	201.0°	1.0°W
Right Tangent Jetty	235°	235.0°	0.0°W
Light House	272°	271.0°	1.0°E
Flag Pole	310°	309.0°	1.0°E
Lookout Tower	345°	344.5°	0.5°E

C.15.b. Observing

- With the above information (column (1) and (2)) proceed to and tie off to the piling.
- With the piling amidships, pivot around it and steer on the objects that were identified, then record the compass heading in column (3). Comparing column (2) and (3) will yield the deviation for that heading (4).
- Use the observed deviation (4) for the indicated magnetic heading (2) as reference points, then draw a deviation curve on the graph as is shown in table below.



C.15.c. Determining

Extract deviation from the deviation curve for any heading.

NOTE

The graph is divided vertically in 15° increments and horizontally in half (for east and west deviation) and then further divided according to amount of deviation. This later subdivision may be greater than the 4° depicted. However, do not tolerate deviations of more than 3° If excessive deviations are noted, the compass should be adjusted by the technique discussed later or by a professional compass adjuster.

C.16. Deviation by multiple ranges

Use the largest scale chart available covering the local area. With parallel rules, triangles, etc., identify as many terrestrial ranges as possible that will be visible when underway, and also provide LOPs across expanses of water with adequate maneuvering room and depth. As far as possible, the ranges should be in the same area, so that variation remains constant.

C.16.a. Preparing

The number of terrestrial ranges available may be limited. However, for each range, deviation will be for both the "steering toward" and the "steering away" (reciprocal) heading. Be careful when "running" the reciprocal heading that the lubber's line of the compass aligns with the axis of the range. Make every effort to identify no less than four ranges to yield deviation values for the cardinal points (N, S, E, W) and intercardinal points (NE, SE, SW, NW).

CAUTION !

Ensure that there are no local magnetic anomalies (such as wrecks, pipe lines, bridges or steel piers) near the boat that could affect the local variation indicated on the chart. Check the chart for any indication of local disturbances.

Determine the magnetic bearing from the chart. Record this information in the format shown below.

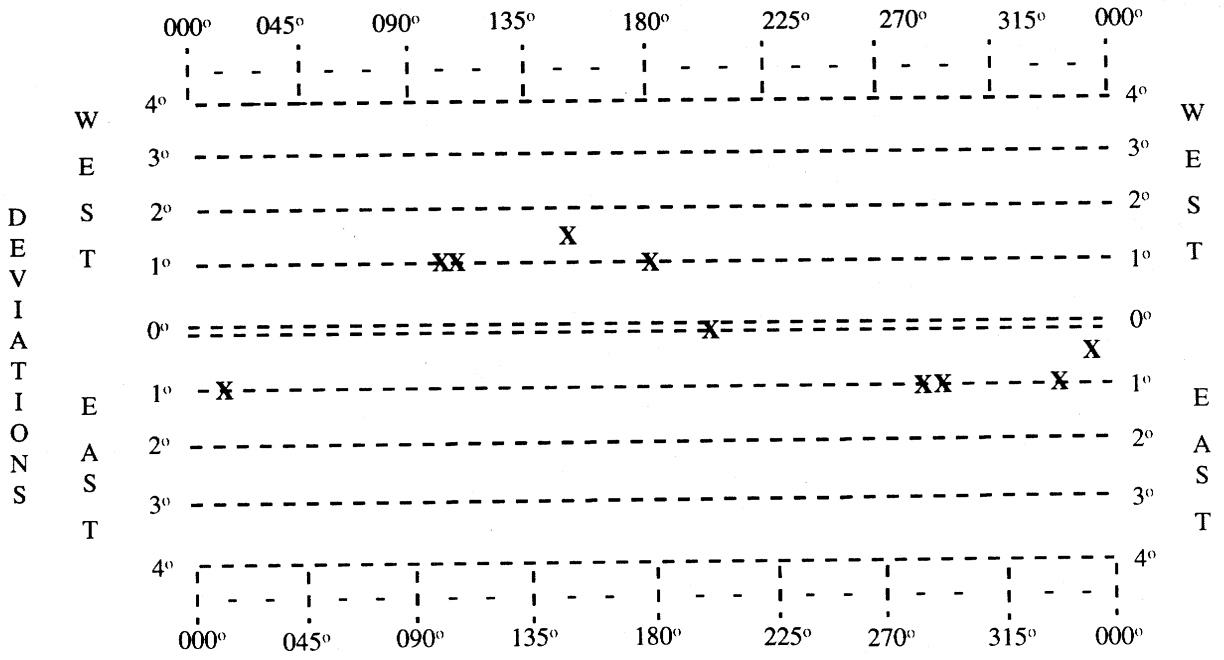
(1) Range (on chart)	(2) Magnetic Heading (plotted)	(3) Compass Heading (measured)	(4) Deviation (calculated)
Steeple -Jetty Lt#4	015°/195°	014°/195°	1°E/0°
R. Tower - Tank	103°/283°	104°/282°	1°W/1°E
Flag Pole - Lt#5	176°/356°	177°/355.5°	1°W/.5°E
Stack - Left Tangent Pier	273°/093°	272°/094°	1°E/1°W
Ent Channel Range	333°/153°	332°/154.5°	1°E/1.5°W

C.16.b Observing

With the information from columns (1) and (2) get underway and "run" the various ranges. Record the compass heading in column (3), as appropriate. Take care not to become so preoccupied with running the range that the boat is in jeopardy of collision, grounding, etc. Comparing column (2) and (3) will yield the deviation from that heading (4).

C.16.c. Determining

The deviation for the indicated headings may be plotted on the deviation graph resulting in a deviation curve. With the resulting deviation curve, deviation for any heading is possible. (See chart below.)


MAGNETIC HEADING
000° 045° 090° 135° 180° 225° 270° 315° 000°
4° 3° 2° 1° 0° 1° 2° 3° 4°
WEST
EAST
DEVIATIONS
WEST
EAST

Compass Adjustment

C.17. Procedure The following is one procedure for adjusting a small boat compass.

Step	Procedure
1	Steer a course in a northerly direction as close to magnetic north as possible as defined by the known objects on the chart. With a nonmagnetic tool, adjust the N/S compensating magnet to remove half the observed error. (Do not try to short cut. Removing all the error in the first step will just overcompensate the error.)
2	Steer a course in a southerly direction. Again remove half the observed error.
3	Steer a course in an easterly direction. Adjust the E/W compensating magnet to remove half the observed error.
4	Steer a course in a westerly direction. Again remove half the observed error.
5	Repeat the above steps, as often as needed, to reduce observed error to the minimum achievable.
6	Record the final observed instrument error for N, S, E, and W.
7	Determine the observed error for NE, SE, SW, and NW. Record these but do not try to adjust these errors manually.
8	Use the recorded values for compass corrections.

This simple procedure is sufficiently precise for most boats. To gain greater precision, use a qualified compass adjuster or consult a book on the subject.

Applying Compass Error

C.18. Procedure

"Correcting" is going from magnetic direction (M) to true (T), or going from the compass direction (C) to magnetic (M). To apply compass error to correct your course or direction :

1. take the compass course
2. apply deviation to obtain the magnetic course
3. apply variation to obtain true course

The sequence of the procedure is outlined below: (See Figure 14-20)

(a) Compass (C)

(b) Deviation (D)

(c) Magnetic (M)

(d) Variation (V)

(e) True (T)

Memory Aid

Applying compass error:

Can **D**ead **M**en **V**ote **T**wice **A**t **E**lection

(**C**ompass) (**D**eviation) (**M**agnetic) (**V**ariation) (**T**rue) (**A**dd) (**E**asterly error)

Add Easterly Errors - Subtract Westerly Errors

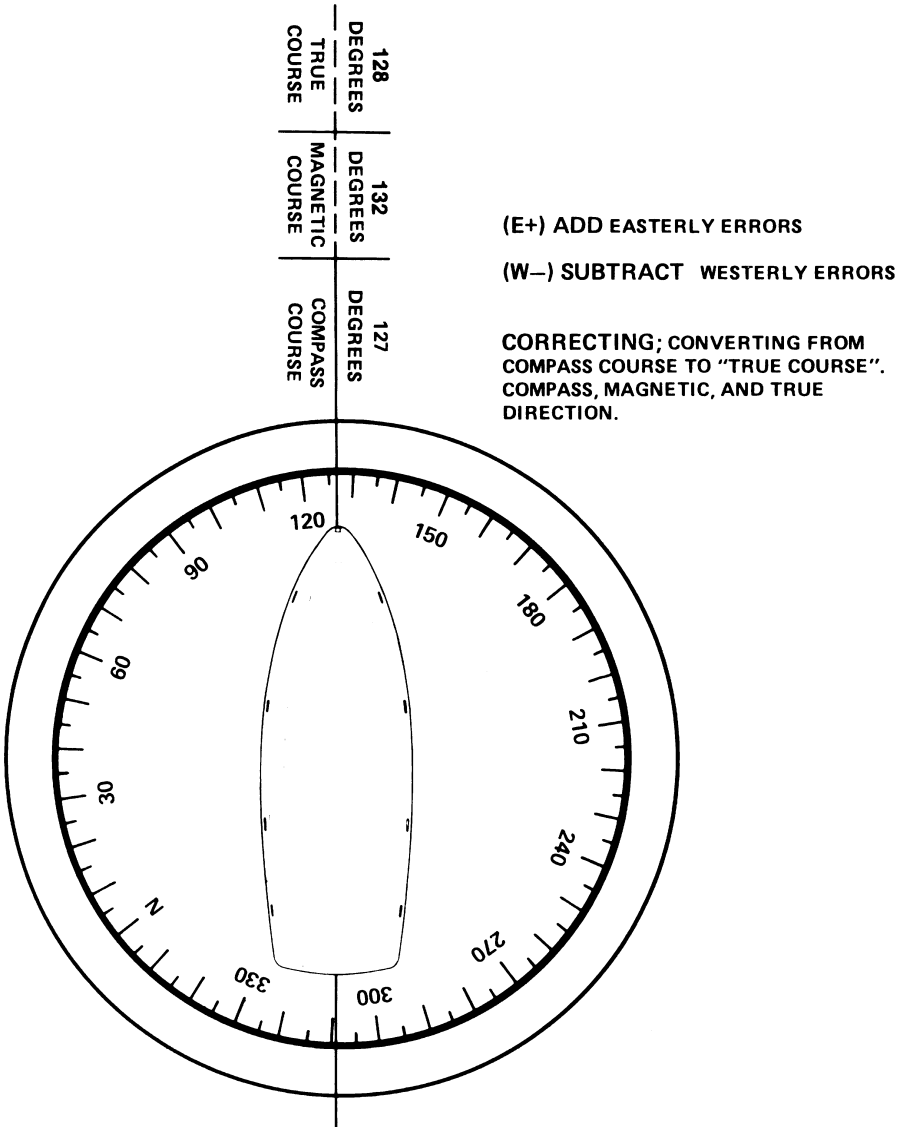
C.19. Obtaining true course

For Figure 14-20, the compass course is 127º, variation from the compass rose is 4ºW, and the deviation from the boat's deviation table is 5ºE. Then, the true course is obtained as follows:

Step	Procedure
1	Write down the correction formula: C = 127º D = 5ºE M = 132º V = 4ºW T = 128º
2	Compute the information you have opposite the appropriate letter in the previous step.
3	Add the Easterly error of 5ºE deviation to the compass course (127º) and you have the magnetic course (132º).

Step	Procedure
4	Subtract the Westerly error of 4ºW variation from the magnetic course (132º).

The true course is 128º.



Applying Compass Error, Correcting
Figure 14-20

C.20. Converting true course to compass course

Converting from true (T) direction to magnetic (M), or going from magnetic (M) to compass (C) is "uncorrecting". For converting from True Course to Compass Course:

1. Obtain your true course.
2. Apply variation to obtain the magnetic course.
3. Apply deviation to obtain your compass course.

The sequence of the procedure is outlined below:

(a) True (T)

(b) Variation (V)

(c) Magnetic (M)

(d) Deviation (D)

(e) Compass (C)

Memory Aid

Converting true course to compass course:
True Virtue Makes Dull Company After Wedding
(True) (Variation) (Magnetic) (Deviation) (Compass) (Add) (Westerly error)
Subtract Easterly Errors - Add Westerly Errors

C.21. Obtaining compass course

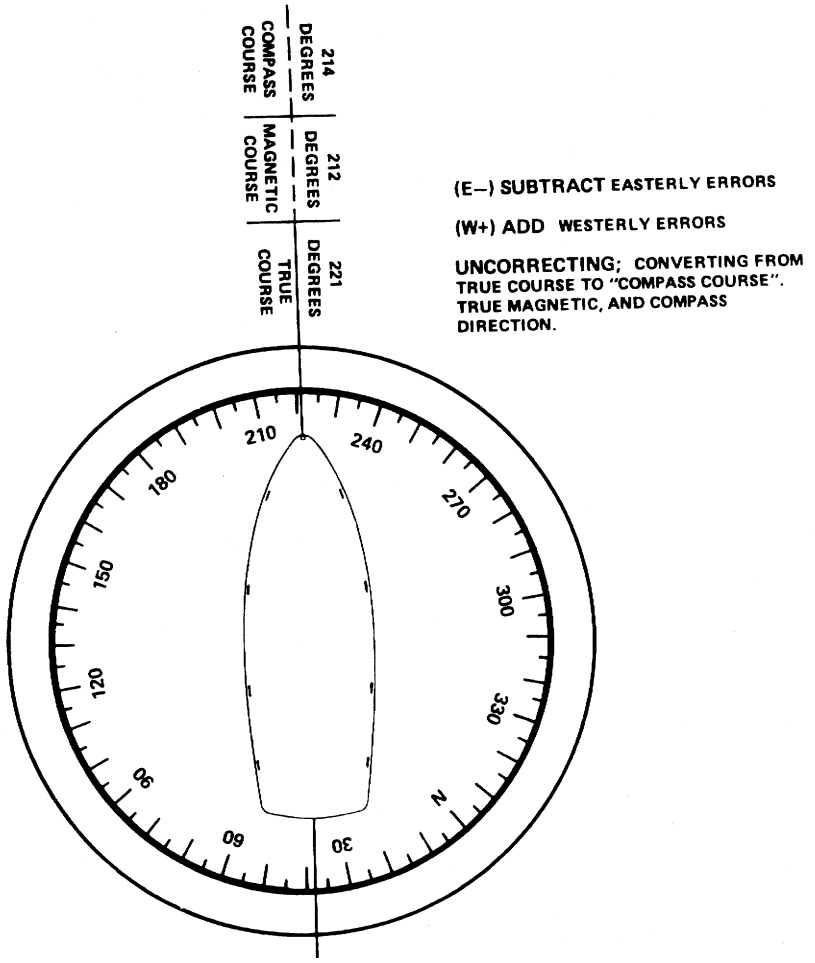
For Figure 14-21, by using parallel rulers, the true course between two points on a chart is measured as 221ºT, variation is 9ºE and deviation is 2ºW.

To obtain the compass course (C) - follow the procedure given below:

Step	Procedure
1	Write down the conversion formula: T = 221º V = 9ºE M = 212º D = 2ºW C = 214º
2	Compute the information you have opposite the appropriate letter in the previous step.
3	Subtract the Easterly error of 9ºE variation from True Course of 221º and obtain the Magnetic Course of 212º.

Step	Procedure
4	Add the Westerly error of 2ºW deviation to the Magnetic Course (212º).

The compass course (C) is 214º.



Applying Compass Error, Uncorrecting
Figure 14-21